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A portion of the literature concerning mechanical teaching machines or devices, which allegedly increase the efficiency and effectiveness of teaching operations by making use of certain psychological principles and teacher laborsaving features, is reviewed.

A classification is made of mechanical teaching aids and devices, suggesting that the stimulus devices and response devices are only teaching aids, while the stimulus-response devices are teaching devices. This review is concerned with one of the three types of stimulus-response devices -- the immediate reinforcers which try to alter the course of learning by automatically presenting the student with a "reward" or reinforcement immediately after he has made a correct response. Those devices discussed are the Pressey multiple-choice device, punchboard devices, chemical paper, the Skinner device, and other miscellaneous devices. Also given are the theoretical issues of reinforcement, transfer, and curriculum; experimental work on teaching devices; and literature endorsements.

Newer types of teaching devices have not been accepted as essential. However, they should be judged in terms of their effectiveness as such other teaching devices as books, blackboards, pencils, and papers. Increased use of stimulus-response teaching devices, which provide for practice of skills, can place mechanical teaching devices in a more prominent classroom role. An index to literature on teaching devices and a bibliography are included.

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"If one of the values of American education is to remain the achievement of individual excellence, some method has to be found to permit more attention to the individual student."

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A Critical Review of a Portion of the Literature on Teaching Devices

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INTRODUCTION

MODERN mass education has to minister an expanded curriculum to increasing numbers of students with a wide range of individual differences in scholastic ability (114, p. 4). This fact, coupled with an increasing student-to-teacher ratio (5, p. 166), has placed schools under pressure of time and numbers. If one of the values of American education is to remain the achievement of individual excellence, some method has to be found to permit more attention to the individual student (25, ch. 20).

One partial solution which may be proposed is concerned with increasing efficiency of the teaching process itself. With increased efficiency of teaching, the teacher-pupil hours per subject matter unit could be decreased. As a result, the pressure of insufficient time would be alleviated, allowing more pupils and greater diversity of curriculum to be handled by a smaller number of teachers.

Teaching efficiency might be increased by two closely related measures: (1) The application of some demonstrably valid psychological principles derived from "learning" experiments, and (2) The use of teaching aids and devices.

The aim of this paper is to review a portion of the literature concerning the so-called "mechanical teaching machines or devices," which, allegedly, increase the efficiency and effectiveness of teaching operations by making use of certain psychological principles and teacher labor-saving features.

Most of these teaching devices embody technological advances of the past thirty years. They are, usually, complex electronic, optical, or electromechanical devices capable of mediating between the student and what he is studying in some unique manner impossible for the teacher using conventional classroom artifacts alone.

The great variety of mechanical devices reflects their devious origins: some are the ideas practicing teachers have found to be successful (13, 14, 47, 68, 71, 100), others have been sponsored by manufacturers who must envision a large virgin market (20, 88, 98). Renewed interest in the tachistoscope, an old psychological research instrument, has been brought

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about by its use in wartime recognition training (69, 83). Research into the psychology of reading has produced numerous devices (9, 23, 30, 31, 74), and certain psychologists have constructed devices which presumably utilize important principles of learning (27, 78, 79, 80, 92).

Although this paper reviews only a small portion of the literature surveyed, a classification of all the devices encountered is felt to be valuable, since: (1) a search of the literature has revealed no other review covering so wide a scope of devices, (2) classification should reveal important differences between devices, (3) the basis of classification will provide a theoretical framework in which literature concerning the devices may be reviewed.

Classification of Mechanical Teaching Aids and Devices

In his attempts to facilitate and direct the course of learning a teacher utilizes various materials as teaching aids. These teaching aids provide the physical stimuli which indicate to a student that certain responses are appropriate. But for learning to take place a student has to make the appropriate responses (48, pp. 1-11). Here, teaching materials provide the setting in which and with which responses may be perfected.

The use of teaching aids as stimuli distinguished from their use as response materials provides the major basis for a classification of teaching devices. Reference to Table 1 will reveal how various devices have been categorized, and some important differences in what may be expected from each class of device.

It should be noted with caution, however, that this classification of devices is not perfect. Many devices fall into one category or another depending upon how they are used. Thus a stimulus device, the motion picture, would have to be classified as a stimulus-response device if provisions were made in the film for audience participation. If a punchboard, classified as a stimulus-response device, were used without any stimulus materials a student would be able to perfect the punching response, but nothing else. Content, in the sense of a curriculum, would be missing. The punchboard would have to be classified as a response device upon the basis of its use.

On the basis of the distinction between stimulus devices, response devices, and stimulus-response devices, it is suggested that the stimulus type and the response type are not teaching *devices* but teaching *aids*, which must be supplemented by some means, usually a teacher, in order to be effective. The term "teaching device," moreover, should be reserved more correctly for the stimulus-response type of device which is capable of teaching without the mediation of a human teacher. The above usage will be followed in this paper.

TABLE 1*

TYPES OF TEACHING AIDS AND DEVICES

Stimulus Devices	Visual	Models Motion picture Motion picture loop Opaque projector Orthographic projector Printing devices Still film projectors
	Auditory	Phonograph Public address Radio Tape
	Audio-Visual	Sound motion picture Television
	Tactile	Braille
Response Devices	Data Manipulators	Abacus Code typewriter Counting devices Desk calculator Typewriter
	Data Gatherers	Alertness indicator Automatic test scorer Classroom communicator Galvanic skin response indicator Recorders
Stimulus-Response Devices	Simulators	Add-a-part films and tapes Dearborn reading film (42) Electronic flight simulators
	Immediate Reinforcers	Pressey multiple choice Chemical paper Electric answer board Punchboard Skinner device Trigger squeeze indicator
	Pacers	Memory drum Metronome Metronoscope Reading accelerators Reading films Tachistoscope

* An index to the literature concerning these devices will be found on page 141.

Stimulus devices, quite simply, do what the subheadings "Visual," "Auditory," "Audio-visual," and "Tactile" in Table 1 suggest. They present a student with information about how to make a given response, or about when it is appropriate to make the response. They do not provide a setting for the practice of responses under specifiable and controlled circumstances. Thus it may be said that stimulus devices provide learning content without any assurance that a learning process will be carried out.

Response devices, on the other hand, do give a student the opportunity to practice responses. They also may be used to gather, record, and transform coded data about the nature of the responses being made. But response devices provide no stimulus information about the circumstances under which particular behavior is appropriate. Thus, responses learned or performed are related to the mechanical properties of the machines and not to any subject matter content.

Stimulus devices and response devices considered separately are truncated representations of the teaching-learning situation. However, when both aspects of learning, the presentation of cues and the opportunity for responding, are combined in one device, stimuli and responses are both placed under control of the teaching device and conditions for learning can be made optimum. Stimulus-response devices (or stimulus devices and response devices used in combination) are designed to present a sequence of stimuli (content) and provide the setting in which appropriate responses may be made and rehearsed (process). Thus stimulus-response devices more nearly reproduce the characteristics of teaching which are required for efficient learning than do stimulus devices or response devices.

Scope and Method of Review

This review is concerned with one of the three stimulus-response types of teaching device: immediate reinforcers. Such restriction of coverage is felt to be warranted because: (1) Stimulus-response devices, on theoretical grounds, most adequately meet the requirements of a teaching device suitable for educational use; (2) There already exist numerous reviews of stimulus type devices (15, 16, 42, 43, 51, 57, 58, 65, 114); (3) Available and educationally relevant literature on response devices is meager; (4) The development of and interest in the immediate reinforcer type of stimulus-response teaching device has been accelerated recently, placing these devices in a controversial position (33, 91).

The order in which articles concerning these devices will be evaluated attempts to follow the sequence: (1) a general description of the devices and their use, (2) theoretical issues involved in their use and the experimentation relating to their use, (3) experimental work, (4) endorsement of the devices.

Each article or group of articles concerning a specific type of immediate reinforcer teaching device will be evaluated in terms of six points, based in part upon a paper by Taves and Gross (97, p. 111). Application of the six points to individual articles will depend upon the alleged purpose of the article. In this way, descriptive articles, for instance, will be held to different but equal standards as theoretical papers. The six points of evaluation are:

1. The accurate and complete description of mechanical characteristics of the devices reported.
2. The theoretical orientation, which includes an adequate statement of theoretical issues to be investigated and their operational definition.
3. The procedures followed, including experimental design and methodology.
4. Manipulation of the data gathered, including the legitimate use of statistical techniques.
5. A reasonable statement of conclusions which takes into account inherent limitations upon generality of the results.
6. The soundness of endorsements recommending use of the devices.

Immediate Reinforcers

General description.—Immediate reinforcers are teaching devices which endeavor to alter the course of learning by automatically presenting the student with a "reward" or reinforcement immediately after he has made a correct response. (Technically, a reinforcement is any environmental event the occurrence of which strengthens the behavior it follows. In teaching devices, the reinforcement is a direct consequence of the student's behavior, usually in the form of confirmation of the correct answer.)

These devices all possess three operational characteristics: (1) they

present a sequence of problem materials to the student, (2) they provide some means by which the student may record his solution to the problems, and (3) they automatically and immediately indicate correctness of the solution. Each of the devices described below presents some variant of this basic paradigm.

Pressey multiple choice device.—In 1926, S. L. Pressey published the description of "A simple device which gives tests and scores—and teaches (78)." This is the earliest article found concerning immediate reinforcer teaching devices, and the first of two articles by Pressey on various models of the same device. Both articles present thorough descriptions, complete with detailed drawings. A description of the final model (79) will present all of the features incorporated into the device.

Stimulus materials are presented in the form of multiple-choice questions and answers printed on standard size typewriter paper. The paper, which is inserted into the device, is moved one question at a time for exposure through a mask which allows only one question and its associated answers to appear. To operate the device, a student reads the question and records the answer of his choice by pressing one of the answer keys which is coded to correspond to the answer alternatives. If the correct answer key has been pressed, the platen advances the paper, making the next question available. If an incorrect answer is given, the next question will not appear and the student has to try again. Counters record the number of correct responses made, and if desired, the device may be set to present a small piece of candy after a predetermined number of correct responses.

When used for the practice of drill materials, the device may be adjusted to discard automatically from the list of questions presented all those which have been answered correctly on previous trials (79). In this way, materials which have already been learned are not unnecessarily repeated.

Punchboard devices.—Only six articles concerning this type of device have been found in the literature (4, 55, 75, 76, 80, 81), and three of the articles are not in educational publications (75, 76, 81). All of the articles present adequate descriptions of the device. The title of the Angell and Troyer paper (4), however, is misleading. Although they cite the Peterson papers of eighteen years earlier (75, 76) which present a similar device, they title their paper "A *new* self-scoring device for improving instruction." The various models of this device differ only in minor details from one another, so that one prototype description will serve for all.

Questions with multiple choice answers are presented in printed form on paper as in a normal testing situation. The innovation lies in the answer marking system. An answer sheet, paper about three by five inches in size, is sandwiched between two heavy, stiff sheets of material of the same size. Rows and columns of holes in the heavy material

delineate the answer spaces, all of the holes in one row representing the alternative answers to one question. Sandwiched between the heavy material under the answer sheet is a template with holes only at the spots that correspond to correct answers. Instead of underlining, checking, or blacking an answer space, the student punches a hole in it. If he punches at the correct spot, his pencil goes through the answer sheet and he knows that he is right. If he chooses the wrong answer, the pencil is stopped by the template under the answer sheet and he has to choose an alternative answer. In addition to letting the student know when he is right, the answer sheet produces a record of the student's performance, including the wrong answers which are indicated by a pencil mark, and the right answers which are indicated by a hole.

Chemical paper.—In addition to their work with the punchboards, H. J. and J. C. Peterson experimented with a chemically treated paper (75, 76). Pressey mentions this device in his 1950 paper (81), but no other researchers seem to have been interested. None of the authors give pertinent chemical data for preparation of the materials.

Questions presented with multiple choice answers were used. The answer space for the correct choice was chemically treated to change color immediately when marked with a special ink. This would inform the student that he had made the correct response. Because the marking ink itself was opaque, a record of all the incorrect responses was also made.

Skinner device.—In a 1954 paper (91), B. F. Skinner presents the description of an immediate reinforcer teaching device. Although Skinner's paper is primarily concerned with development of a theoretical rationale for the application of his teaching device in schools, it would be of value to some readers to have more technical specifications of the device. The thoroughness and detail of description do not match those of Pressey's articles (78, 79).

Physically (91, p. 95), the device is a box "about the size of a small record player." On the top surface of the box is a window through which appears problem material printed on paper tape. Operation of answer keys just below the window causes the answer to appear through holes in the paper tape. If the correct answer has been set, the student may advance the tape to the next problem by turning a knob which also resets the answer keys back to zero. If desired, turning the knob may be made to ring a bell or give other conditioned reinforcement. Provision is made for counting wrong answers.

Although different in physical appearance, Skinner's device is essentially a modification of the Pressey device. The Pressey device uses multiple choice answers with each of the answers represented by one answer key. This constrains the possible number of answers which may be given by a student and also makes it necessary to present the correct answer. Skinner's modification overcomes the answer constraint by: (1) using as content arithmetic operations producing answers up to four digits, and

(2) using four answer keys, each capable of representing the digits 0 through 9. The choice of subject matter content places inherent constraint upon the number of answers possible, and the positions of the answer keys cover the entire range of content. The consequence of such an arrangement is that students have to compose their answers rather than to choose them from among multiple choice answers which may be very similar to the correct answer. The advantages of such an arrangement are that it prevents the accidental conditioning of incorrect answers, and provides a closer approach to the conditions upon which the answers will be useful in the future. Of course, the design of machines capable of handling materials less constrained than arithmetic becomes very complex, but is still feasible.

The other major contribution by Skinner does not reside in the device but in the organization of subject matter presented by the device. Other devices have been used to present groups of questions, relatively unrelated to one another, about some subject matter area. Skinner presents an organized sequence of materials in which successive problems are dependent upon earlier materials (91, p. 95). Successive steps of the subject matter are small so that if the previous problem has been solved correctly there is very little chance that the present one will not be also (91, p. 94). This raises the frequency of reinforcement to a maximum, and reduces the possibility of the aversive consequences of being wrong.

Of course, this type of subject matter scheduling would be extremely difficult in more amorphous areas than mathematics, but in constructing subject matter programs, Skinner deals with the problems of curriculum choice, step, and sequence which are important in all teaching. The criterion for using a particular problem as subject matter is simply that the students must be able to get it right. If the problem cannot be solved by most students, then it is either the wrong problem, at the wrong place in the sequence, or else it is too large a step from the previous problem.

Miscellaneous devices.—H. B. English describes a device he designed and used during the year 1918 to assist in training soldiers to squeeze rather than jerk a rifle trigger (34). A tambour was attached to the trigger mechanism of one rifle and connected by rubber tubing to a manometer. Movement of the trigger created a pressure differential which caused liquid in the manometer to move. If the trigger was squeezed properly, the liquid slowly changed level; if the trigger was jerked, the liquid jumped. The author claims great success for this device in teaching poor riflemen to fire correctly. A similar device might be useful in the teaching of handwriting to indicate evenness of pencil pressure or smoothness of pencil stroke.

The electric answer board presents a series of questions and answers which the student attempts to match. To check the correctness of a guess, the student touches a contact button next to the answer of his choice with an electric probe. If the answer is correct, a light flashes or a signal

sounds. For incorrect choices, nothing happens. Although this is a common children's toy, no articles were found concerning its use in teaching.

Theoretical issues: reinforcement.—Although there are differences in theoretical explanations of why reinforcement works (48, ch. 3; 53, ch. 6), there can be no doubt that it is effective in the training of laboratory animals. It is also well established that reinforcement is most effective when administered as quickly as possible after a response has been made (53, pp. 135-142). The designers of immediate reinforcer teaching devices, have made certain assumptions, however, which are not as well documented. These assumptions, which will be discussed below, are related to the following areas:

1. Generalization of results from animal studies to homo sapiens.
2. Control of the conditions which make knowledge of results reinforcing.
3. Type of reinforcement used.
4. Quantity of reinforcement.
5. Schedule of reinforcement.

A large part of learning theory research has used the laboratory rat, but there are numerous studies demonstrating the efficacy of reinforcement with human subjects (123, pp. 685-693; 68A, pp. 374-485). Skinner claims that, "In all this work the species of the organism has made surprisingly little difference. . . . Comparable results have been obtained with pigeons, rats, dogs, monkeys, human children, and most recently . . . human psychotic subjects (91, p. 89)." Warren and Brown (109), who had children learn a bar pressing response in a nursery play situation conclude, "The conditioning, extinction, disinhibition and periodic reconditioning of an operant response in children are essentially similar to these phenomena in rats (109, p. 203)."

Despite evidence and claims for reinforcement as a fundamental datum of all learning, generalizations from one species to another and from the experimental laboratory to the classroom should be made with caution. The laboratory almost invariably has used solitary subjects, while the classroom provides a chance for complex social interaction. Such interaction may alter the conditions under which certain reinforcements are effective. This is illustrated by recent studies in which Auble and Mech attempted to show the effects of verbal reinforcement in classroom situations (7, 8). There were three groups of subjects: one group was reinforced by verbal praise in front of the entire class; the second group heard praise administered to the first group; and the third group, in another classroom, neither heard nor received verbal praise. When arithmetic achievement of the three groups was compared, the non-praise group unexpectedly did better than either of the praise reinforced groups (8, p. 312). These results may be due to lack of adequately equated groups, accidental praise received by the third group, or by the use of

unusual public acclaim which interfered with the reinforcement of arithmetic achievement by disrupting the praised groups' "social structure."

The traditional reinforcers in psychological experimentation have been food, water, and electric shock. There is good reason for their use: all animals will avoid electric shock, hungry or thirsty animals will work for food or water, and it is relatively simple to control the degree of motivation by varying hours of deprivation or intensity of shock. Since it is unethical to shock, starve, or dehydrate children (12), other reinforcers have to be used with teaching devices. Skinner has suggested that exploratory and manipulative activities are reinforcing enough to keep a student at work with a device (91, p. 95). Recent experimental studies suggest that this is so (123, p. 685), but it has also been found that an organism's "curiosity" becomes satiated by prolonged exposure to novel situations (123, p. 671). Under such circumstances, manipulation and exploration no longer provide adequate reinforcement. To make exploratory activities reinforcing again the organism has to be removed for a period of time from the formerly novel situation. This restores the effectiveness of reinforcement.

Any teaching device used almost continuously in the classroom would face the same problem of satiation. Unfortunately, none of the authors reviewed deal with this problem. One method of avoiding satiation would be to mete out reinforcement in small doses. Another method would be to have alternative reinforcers available.

Although no author treats in detail the problem of what alternative reinforcers might be used, Skinner suggests several: social approval, desired activities, and as a last resort, aversive stimulation (91, p. 93). By including a candy delivery attachment on his device (78), Pressey indicates belief that the presenting of sweets can be reinforcing. All of the above events and many more, can be made contingent upon a student's performance with the teaching device. Whether these events will serve as satisfactory reinforcers will not be known until they are tried (16a).

Most of the authors of articles concerning immediate reinforcer teaching devices are content, however, to side-step the problem of what reinforcers to use. They claim efficacy of their devices is due to "knowledge of results" (4; 63, p. 45; 81, p. 418). Indeed, it has been amply demonstrated that knowledge of the correctness of one's own responses improves performance of a task (123, p. 686). Almost all tasks require some sort of sensory feedback from the environment; this is what knowledge of results provides. However, "knowledge of results" is a descriptive term which refers solely to a particular kind of sensory feedback, not to the reinforcing value of the feedback. The conditions under which this kind of an event attains and maintains reinforcing value are little understood, but if mechanical teaching devices are to be used successfully, educators will have to discover and use the contingencies which are available and most effective in making knowledge of results reinforcing.

Besides type and quantity of reinforcement, the schedule of reinforcement has important effects upon the course of learning. The rate at which a subject will respond, the course of extinction of a response, and the regularity of response all may be brought under the control of reinforcement scheduling (90, pp. 71-77). Since distribution of practice depends upon the rate of responding, which is controlled by reinforcement scheduling, rote learning phenomena (retroactive inhibition, reminiscence, recall) may also be important (64, ch. 4). There is no mention of this in any of the papers reviewed, much less is there any relevant experimental work concerning this aspect of teaching devices.

Theoretical issues: transfer.—Successful transfer of training from the teaching device to "real" problems is the ultimate criterion of a teaching device's effectiveness. Yet Pressey is the only author to even mention transfer as an area for research. He says,

> The . . . question is as to whether reactions of the key pressing type are so different from the reactions to be made in use of the materials being learned as to present a serious problem of transfer. . . . Briefly, it may be said that in much school learning there is some analogous problem of transfer; the objection is not believed serious (79, p. 552).

The fact that much school learning is faced with problems of transfer, however, does not minimize the problem. Successful design and use of mechanical devices requires the establishment of their validity through the measurement of transfer value.

Illustrative of the type of work needed is a 1939 study by Votaw and Danforth which investigates the effect of method of response upon the validity of multiple choice tests (107). Equated groups were given the same test, but marked their answers differently; by use of a keyed answer sheet, by underlining, and by checking answer spaces. There was found to be a significant difference in scores which depended upon the answer marking method and was positively correlated with the scores of the subjects on a test of mechanical-transfer ability. The authors conclude, "Apparently the resulting scores represent in part an ability in mechanical-transfer as well as an ability in the subject matter (107, p. 627)."

It should be expected that what a student learns through use of a mechanical teaching device will depend in part upon characteristics of the mechanism itself and in part upon the subject matter content which is deliberately presented. Studies similar to the above are needed in order to discover the conditions which will minimize "learning about the machine" and thus maximize learning and transfer of the desired subject matter.

Theoretical issues: curriculum.—In all of the articles reviewed, immediate reinforcers have been looked upon as teaching and testing devices. No author has mentioned the obvious usefulness of such machines in curriculum research.

Mechanical devices can go far toward eliminating the "teacher effect" in educational investigations. Curriculum materials can be presented to equated groups of students in exactly equivalent manners in order to test the influence of different materials or arrangements of material. The machine removes one heretofore always present source of variation: the use of different teachers, or the same teacher attempting to teach different groups in the same manner.

Experimental work.—There have been found but four experimental articles published on immediate reinforcer teaching devices. Three of the experiments reported are concerned with punchboard devices (4, 63, 81), one with chemical paper (76), and one with the Pressey answer key device (63). This certainly does not represent enough experimental work to provide an adequate evaluation of these devices, especially considering the general nature of the work which has been done. All of the experiments attempt to compare the results of mechanical device teaching with "usual" classroom teaching.

The procedure which has been followed is to obtain approximately equated groups of students, and expose one group to the usual classroom methods of teaching, whatever they may be, and the other group to mechanical device teaching utilizing the same subject matter. Effectiveness of the two teaching methods is then evaluated by comparing the scores the two groups of students obtain on identical tests.

Such experimentation may indeed show an advantage for one or the other method of teaching, but there is no guarantee that the results obtained can be replicated, for the outcome of those experiments depends upon unspecified parameters of the "usual" classroom situation. As stated by one group of researchers, "The complexity of the teaching-learning process is such that attempts to establish the relative merit of a 'general method' of teaching are likely to prove inconclusive (46, p. 205)." To be of value, investigations concerning mechanical teaching devices, or any other method of teaching, have to deal with the variables which lie behind the presumed superiority of the method.

The three studies involving the punchboard report superior results from use of that device. But it is maintained here that the results are not due to any demonstrated advantage of the punchboards, but to the experimental procedures followed.

Jensen (55) chose as subjects groups of superior students who wished to accelerate academically. Instead of following the usual classroom procedures in an educational psychology course, they attended a "laboratory" *ad libitum* where they could study, discuss, and test themselves with punchboards. The punchboard tests covered assigned reading in the course, and each question had a page reference next to it so that if a question was missed a student could look up the topic and correct himself. Final course grades of the experimental subjects were superior to those of students attending regular classes.

It is quite obvious that the results obtained may be due to constitution of the experimental group, use of the "laboratory" setting, use of the punchboards, or all three to varying degrees.

In a series of experiments reported by Pressey (81), the punchboard is used in essentially the same manner as by Jensen, to help a student discover what he does not know and thus guide himself to needed further study. In these experiments the test scores of subjects using the punchboard are compared with those of control subjects using conventional multiple choice tests (81, pp. 426-430) or "carefully planned" classroom discussion (81, p. 431). Use of the punchboards produced consistently higher scores.

Pressey implies that the difference in scores is due to the "quick incisiveness" of the punchboard (81, p. 418). Actually, immediacy of reinforcement may have nothing to do with the results obtained. It is likely that many of the control subjects using conventional multiple choice tests never went over their test results and thus received no information about what they needed to study. Not having taken *any* tests, it is probably more likely yet that the discussion groups did not find out in what areas they needed study. Thus the fact that the punchboard group received superior test scores may have been because the control subjects received no information concerning their own lack of knowledge. That is, immediacy of reinforcement of the punchboard groups was not responsible for their *superiority*, but lack of knowledge of results in the control groups was responsible for their *inferiority*.

This interpretation is supported by the 1929 experiment of Curtis and Woods in which students who corrected their own tests subsequently received higher scores than students whose tests were corrected by the teacher (26). Since there was no chance for immediate reinforcement by knowledge of results to take place soon enough to be effective (53, pp. 136-140), the difference in the scores was probably because the group that corrected its own tests was forced to see the mistakes, while the teacher corrected group was not.

The same sort of criticism is applicable to the studies of Peterson (76), utilizing chemical paper and Little (63), using both the punchboard and the Pressey device. Methodologically, however, the Peterson and Little researches are superior to those of Pressey and Jensen in both experimental design and statistical analysis. Pressey and Jensen present only average scores for their experimental and control groups. Thus there is no way of determining whether results are significant or not. Peterson and Little, on the other hand, compute the standard error of the difference scores, which does make this information available. Peterson is the only investigator to use other than a simple experimental-control group design. He replicates his experiment, interchanging the experimental and control groups for the replication. In this way, any original differences in the groups are exposed and the data may be corrected.

It can be stated that the research so far performed shows that immediate reinforcer teaching devices probably aid students in attaining higher test scores than the various alternative classroom procedures with which the devices have been compared. However, it cannot be stated that use of immediate reinforcer devices will produce higher test scores than conventional classroom procedures in general. Nor may it be claimed that the results so far obtained are due to immediacy of reinforcement provided by the devices. A crucial test of the value of immediate reinforcement has to meet the following, so far unattained, criteria: (1) Provide both experimental and control groups with knowledge of results, making sure that both groups receive equivalent information about the correctness of their responses. (2) Reinforce subjects in the experimental group as quickly as possible after a response has been made. (3) Delay reinforcement of the control group.

Literature endorsements.—Authors of articles on immediate reinforcer teaching devices make the following claims for their devices:

1. They are time- and labor-saving for teachers (63, p. 49; 78, p. 376; 80, p. 671).
2. They are effective because they provide immediate reinforcement (81, p. 418; 91, p. 95).
3. They are more effective in consistently delivering immediate reinforcement than a teacher can be (91, pp. 94f).
4. They can deal effectively with the range of individual differences present in a classroom (91, p. 95).
5. They are able to teach the complex relationships involved in verbal thinking (91, p. 96).

There can be no argument about the time- and labor-saving characteristics of devices which present a set of materials to a student and then score and record the results of his endeavors. The teacher is relieved of three tasks: making up and arranging the curriculum, reinforcing the student, and scoring tests.

With individual children operating a machine, the materials presented can be made suitable for the particular child, and the machine can be made to reinforce the child more consistently than a teacher who has to deal with many children. This sort of claim is intuitively obvious. But claims that such devices can be used successfully in all subject matter areas are premature. Perhaps, hypothetically, teaching devices can be used to teach such complex behaviors as verbal reasoning in social studies, for instance, but at the present stage of technological development they are incapable of dealing with a large enough repertoire of student responses.

This may be the basis for some of the objections voiced against "education by machine" (78, p. 376; 91, pp. 96f). Critics cannot conceive that complex human endeavors could be analyzed into the precise sort of units

suitable for mechanical presentation. Authors of articles on mechanical devices can avoid this sort of resistance if they emphasize the ways in which their devices can help now, at the present stage of development, rather than predicting future successes in less obvious areas.

Acceptance and Use of Mechanical Teaching Devices

Although not usually considered as such, almost all classroom paraphernalia are teaching aids and devices (cf. 74, p. 6). Books, blackboards, pencils and paper have been so long a part of teaching that they are accepted, perhaps, as essential to the teaching-learning process. Newer types of mechanical teaching devices, however, have not been accepted as so essential. As the following quotations show, they tend to be thought of as ancillary to the teaching situation:

> In general, the elaborate mechanical devices should be regarded as a last resort to be used when other methods have failed . . . (40, p. 354).
> . . . instruments . . . are not a substitute for a good teacher (94, p. 47).
> Audio-visual devices can and should, from time to time, be used in the classroom but their proper place is in the language laboratory. Many teachers who believe in the oral approach justly feel that they could get better results if they were given smaller classes and more hours per class rather than more machines (41, p. 285).

Authors of the above quotations fail to perceive that conventional classroom paraphernalia and the newer optical, electronic, and electromechanical types of device actually have the same basic function: they provide the manipulanda and discriminanda upon which learning is based. Therefore, mechanical devices should not be placed in a special category, but should be judged in the same manner as other teaching devices, in terms of their effectiveness. Judging their effectiveness should include determination of the exact conditions under which the devices will do what they are designed to do. This may prevent: (1) overgeneralization of teaching results expected and, (2) incorrect and unsuccessful utilization, and subsequent casting aside of what may be excellent devices when correctly used.

There may be a rational basis for the opinions quoted above, however. Examination of Table 2 will reveal that over 90 per cent of the teaching devices in use probably are the stimulus type of teaching aid (73, p. 138).

TABLE 2
Percentage of Schools Using Devices

Device	Percentage
Motion picture	58.1
Phonograph	58.1
Radio	24.2
Public address	12.3
Opaque projector	11.3
Recorder	9.9
No devices	6.9
Other	2.4

Such devices provide a student with information and may motivate activity, but stimulus devices do not provide for the rehearsal or practice of behavioral responses appropriate to the "basic" skill areas of schooling, such as reading, spelling, writing, and arithmetic. In not being able to deal with the skill acquisition areas of school work, stimulus teaching devices are indeed peripheral, and the opinions quoted, valid. It may be that increased use of stimulus-response teaching devices, which do provide for practice of skills, will place mechanical teaching devices in a more prominent classroom role.

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Code typewriter	11
Counting devices	96
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Desk calculator	20, 88
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Galvanic skin response indicator	23
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Phonograph	19, 41, 45, 57, 58, 65, 72, 73, 114
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